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Effects of Nitrogen Fertilization Management Practice on the Yield and Straw Nutritional Quality of Commercial Rice Varieties

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ABSTRACT

An experiment with treatments comprising of five nitrogen rates (0, 120, 160, 200 and 240 kg N/ha) was carried out to assess the effects of nitrogen fertilization management practice on the grain yield and straw nutritive quality in two commercial rice varieties; MR 211 and MR 219. Increases in nitrogen application was found to increase ($P<0.01$) the grain yield, total spikelets per square meter, number of spikelets per panicle and straw crude protein from 4.56% to a maximum level of 8.45%. It also decreased ($P<0.05$) the *in vitro* true dry matter organic digestibility (IVTOMD) from 59.1% to 55.14%, neutral detergent fiber (NDF) and acid detergent fiber (ADF). There were varietal differences in the straw nutritional properties, where MR 219 had higher NDF, hemicellulose and cellulose ($P<0.05$) concentration where as MR 211 had higher amount of acid detergent lignin (ADL) ($P<0.01$) and silica ($P<0.05$) in the straw. Between the two varieties, MR 219 is superior to MR 211 in view of the higher grain production and grain: straw ratio. The result from correlation between agronomic characteristics and straw nutritive quality implies that rice varieties with good agronomic characteristics have potential in yielding straws with better nutritive quality.

INTRODUCTION

Rice is the staple food for Malaysians. As population increases, there is need to increase the rice grain production to enhance food security. The target of the Ministry of Agriculture and Agro-based Industry Malaysia is to increase the rice grain yield from current average yield of 4.5 t/ha to 10 t/ha (MOA, 2004a). Among the steps that have been taken to achieve this target are the application of high levels of nitrogen fertilizer and the use of high yielding varieties in rice establishment. Farmers are currently applying more than the recommended rate of 170 kg N/ha as they believe that higher nitrogen levels are essential in maximizing grain yields (Alias and Manaf, 1993).

The 684 000 hectares of rice fields in Malaysia produced 1.3 million tonnes of rice straw annually (MOA, 2004b). The burning of rice straw and stubble in Malaysian rice field still remain as cultural and current practice of its disposal. Since large amount of straw produced is disposed by burning which is not only wasting resources but also causing environmental hazards, alternative uses of rice straw have been suggested and one of them is utilizing the rice straw as ruminant feed. It has been reported that the nutritive composition and digestibility of rice straw varies widely among different varieties (Doyle *et al.*, 1986; Vadiveloo 1992, 1995; Abou-El-Enin *et al.*, 1999) and environmental (fertilizer application, season, location) condition (Roxas *et al*., 1984; Ibrahim *et al*., 1988; Shen *et al*., 1998). The current practice of applying high rates of nitrogen fertilizer by the Malaysian rice farmers in targeting high grain production have prompted further study on the impact of this fertilizer practice on the straw quality and production.

In Malaysia, rice straw which is the crop by-product is regarded as a waste and has not been used as ruminant feed; therefore most of the straws are burned following grain harvest. If it is proven that the current nitrogen fertilizer practice can improve the straw nutritive quality, then it would be worthwhile using the straw for ruminant feed rather than being disposed by burning.

This paper aims to assess the effects of nitrogen fertilization management practice on the grain yield and straw nutritive quality in two commercial rice varieties.

MATERIALS AND METHODS

The field experiment was conducted in Universiti Putra Malaysia. Two rice varieties, MR 211 and MR 219 were grown under five levels of nitrogen application at 0, 120, 160, 200 and 240 kg N/ha in a Completely Randomized Design (CRD) with four replications. Split urea ($CO(NH_2)_2$) fertilizer were applied at 15, 35, 55 and 75 DAS.

The rice plants were harvested (MR 211 at 105 DAS; MR 219 at 115 DAS) manually using sickles at 12 cm above ground. The grains were separated from the straw following harvest. The straws was separated into leaf (including blade and sheath) and stem fractions. The straw samples were oven-dried at 60 ^{o}C for 48 hours and ground for chemical analysis. The agronomic characteristics and yield components of each rice variety were recorded.

The crude protein was determined by Association of Official Analytical Chemist (AOAC, 1984). Chemical composition for NDF, ADF and ADL were analyzed according to the procedures of Goering and Van Soest (1970) and silica was determined according to the method as described by Smith *et al*. (1971). The *in vitro* digestibility was analyzed using *in vitro* gas production technique as described by Menke and Steingass (1988).

The data were analyzed using analysis of variance, regression and correlation procedure of SAS Institute Inc., USA. Factorial experiment was carried out to determine the existence of interaction between the sources of variation. F-test and Duncan Multiple Range Test (DMRT) were carried out for means and comparison between the treatments. Regression analysis was carried out to determine the relationship between the nitrogen levels and straw chemical composition. Correlation analysis was carried out to determine the relationship between the plant agronomic characteristics and chemical composition.

RESULTS

The analysis of variance (ANOVA) as shown in Table 1 indicate the effects of nitrogen levels and varieties and their interactions on the yield performance and agronomic characteristics.

TABLE 1: Significant levels from analysis of variance on the yield performance and agronomic characteristics in two commercial rice varieties.

Source of variation	Degrees of freedom	grain yield (t/ha)	grain: straw	spikelets/ m^2	spikelets/ panicle	stem height (cm)
Nitrogen (N)	4	**	ns	***	***	***
Variety (V)	1	***	***	**	ns	*
N x V	4	ns	ns	ns	ns	ns
CV		27.37	29.31	31.03	20.66	9.87

***P<0.001; **P<0.01; *P<0.05; ns P>0.05

Increment in the number of spikelets per panicle occurred with increasing nitrogen rates. The production of spikelets per square meter was increased significantly (P<0.001) with nitrogen fertilization. Increase nitrogen rates was shown to increase the grain yield (P<0.01).

The highest grain yield produced was 8.53 t/ha under maximum nitrogen application at 240 kg N/ha TABLE 2 Variety MR 219 produced higher grain yield and grain: straw ratio compared to MR 211.

TABLE 2: Effects of nitrogen rates on yield performance and agronomic characteristics of two commercial rice varieties

	Variety	Nitrogen rate (kg/ha)					Variety
		0	120	160	200	240	mean
Grain (t/ha)	MR 211	4.02	5.64	5.06	6.28	6.54	5.51z
	MR 219	6.66	5.69	6.58	10.55	10.51	8.10y
	N rate mean	5.34b	5.67b	5.82b	8.42a	8.53a	6.76
Grain: straw	MR 211	0.51	0.58	0.57	0.76	0.65	0.61z
	MR 219	0.9	0.72	0.81	1.03	0.94	0.88y
	N rate mean	0.71	0.65	0.69	0.9	0.8	0.75
Spikelets/ panicle	MR 211	74	92	111	147	171	119
	MR 219	83	87	111	147	159	117
	N rate mean	79c	90bc	111b	147a	165a	118
Spikelets/m2	MR 211	38 199	49 574	44 395	60 695	68 220	52 217z
	MR 219	60 023	48 966	56 482	95 528	102 385	72 677y
	N rate mean	49 111b	49 270b	50 439b	78 112a	85 303a	62 447
Stem height (cm)	MR 211	41.9	47.18	55.23	59.03	62.03	53.07z
	MR 219	46.15	53.7	55.68	63.35	67.93	57.36y
	N rate mean	44.03c	50.44b	55.46b	61.19a	64.98a	55.22

Means with the same superscripts are not significantly different (P <0.05), according to DMRT

The crude protein concentration in the whole straw, leaf and stem fraction was found to increase (P<0.01) with nitrogen fertilization level (Figure 1). The maximum crude protein obtained was 8.45 %(whole straw), 9.88 %(leaf) and 6.77 %(stem) under optimum nitrogen application at 240 kg N/ha. The leaf fraction was found to contain higher crude protein concentration compared to the stem. A quadratic decline in the NDF concentration was observed with increasing nitrogen fertilization level (Figure 2). The result suggests that increasing nitrogen level up to 160 kg N/ha reduces the cell wall concentration in straw but further increases in nitrogen level raised the cell wall concentration especially in the stem fraction.

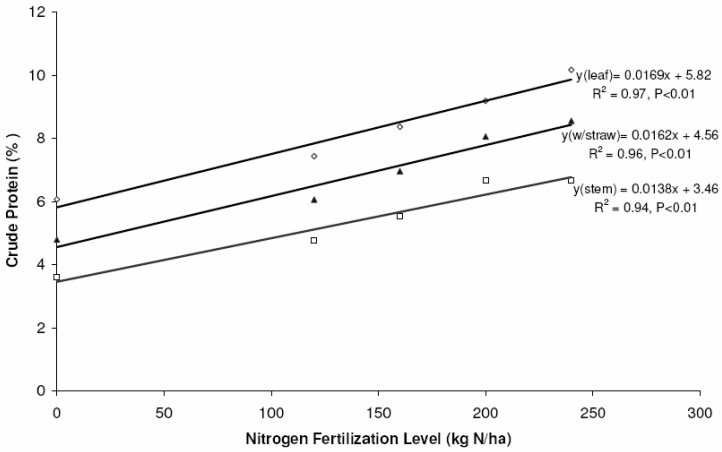

Figure 1: Effects of nitrogen rates on the straw crude protein

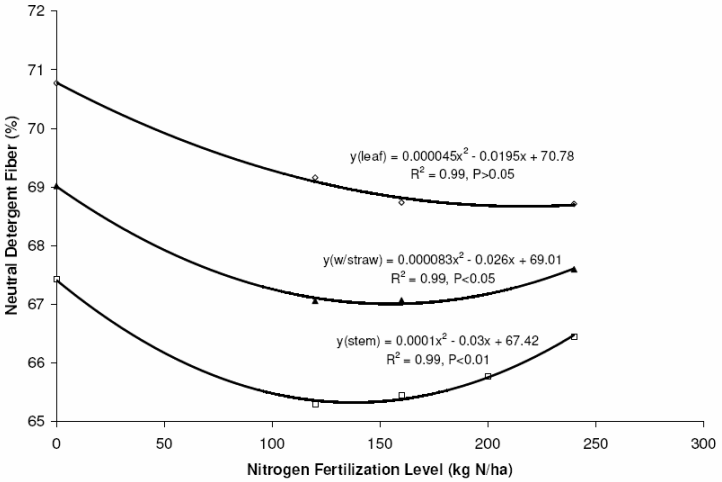

Figure 2: Effects of nitrogen rates on the straw neutral detergent fiber (NDF)

Increasing nitrogen fertilization level resulted in a linear decline in the ADF concentration in whole straw (P<0.05), leaf (P<0.01) and stem (P<0.05) fraction (Figure 3). Varietal differences in the straw nutritional composition in each botanical fraction are shown in Table 3. MR 211 had higher ADL and silica concentration where as MR 219 had higher NDF, hemicellulose and cellulose concentration (Table 3).

Increasing nitrogen fertilization level was shown to decrease the *in vitro* true organic matter digestibility (IVTOMD) significantly in the stem ($P<0.05$) fraction (Figure 4). The stem was found to have higher digestibility compared to the leaf.

TABLE 3: Varietal differences on thestraw nutritional composition

Nutritional composition (%)	Variety	Botanical Fraction		
		whole straw	leaf	stem
NDF	MR 211	66.83a	67.87b	65.93a
	MR 219	67.85a	69.62a	66.23a
	Significant level	ns	*	ns
ADL	MR 211	4.80a	6.21a	3.12a
	MR 219	3.04b	4.21a	1.92b
	Significant level	**	ns	***
Hemicellulose	MR 211	26.45b	26.18b	26.98a
	MR 219	27.65a	27.56a	27.73a
	Significant level	*	*	ns
Cellulose	MR 211	28.47b	26.67b	30.69a
	MR 219	30.28a	29.0a	31.51a
	Significant level	**	*	ns
Silica	MR 211	6.71b	8.37a	4.79a
	MR 219	5.72a	7.38b	4.06b
	Significant level	**	**	*

***$P<0.001$; **$P<0.01$; *$P<0.05$; ns $P>0.05$

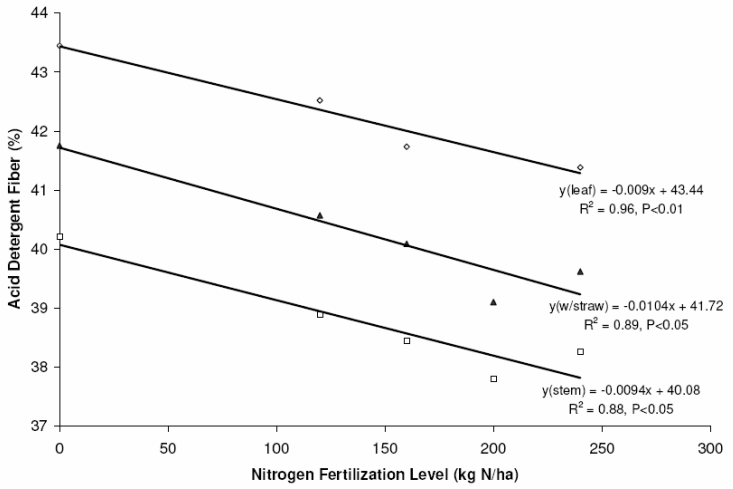

Figure 3: Effects of nitrogen rates on straw acid detergent fiber (ADF)

Table 4 showed that the grain yield, stem height and leaf: stem ratio were positively correlated with the crude protein. This positive correlation indicates that, increased grain yield, stem height and leaf: stem ratio increased the straw crude protein. The grain yield and stem height were negatively correlated with NDF and ADF. This negative correlation implies that the increased in grain yield and stem height decreased the straw cell wall (NDF) and fiber (ADF) fractions.

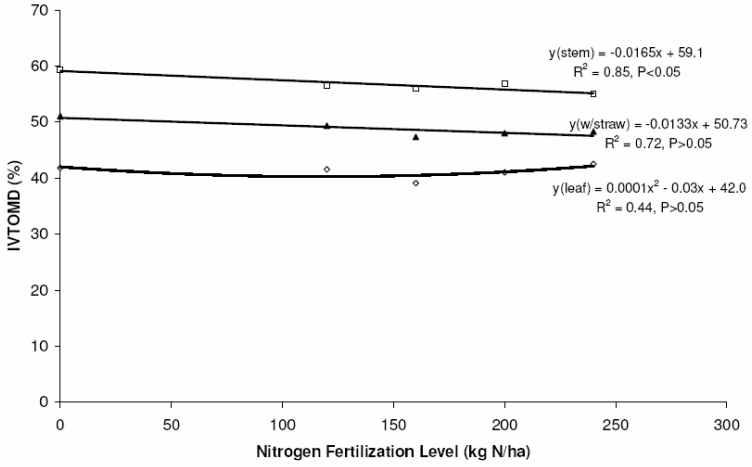

Figure 4: Effects of nitrogen rates on *in vitro* true organic matter digestibility

TABLE 4: Correlation between yield performance, agronomic characteristics and straw nutritional properties

	CP	NDF	ADF	IVTOMD
Grain yield	r = 0.31 *	r = -0.02 ns	r = -0.17 ns	r = 0.15 ns
Stem height	r =0.57 ***	r =-0.39 *	r = -0.55 ***	r = -0.15 ns
Leaf: stem	r = 0.57 ***	r = 0.05 ns	r = 0.08 ns	r = -0.55 **

***P<0.001, **P<0.01, *P<0.05, ns P>0.05
CP: Crude Protein, NDF: Neutral Detergent Fiber,
ADF: Acid Detergent Fiber,
IVTOMD: *In Vitro* True Organic Matter Digestibility

DISCUSSION

The maximum crude protein concentration of 8.45% in the whole straw fraction in this present study was not only higher than those reported by Roxas *et al*. (1985), Ibrahim *et al.* (1988), Bainton *et al*. (1991) and Drake *et al*. (2002) but also higher than in chemically treated straw reported by Vadiveloo (1996). The result shows that nitrogen fertilizer applied at rate above 160 kg N/ha is adequate to obtain the crude protein above 7% in the whole straw; which is the critical crude protein level required for voluntary feed intake in ruminants. The result recommends that it is worth while to apply higher rates of nitrogen fertilizer as it was found to improve the straw crude protein while at the same time producing high grain yield. The NDF and ADF concentration in this present study were lower compared to the traditional Malaysian rice straw varieties reported by Devendra *et al*. (unpublished, reviewed by Doyle *et al*., 1986). This result is in agreement with earlier observations (Devasia *et al*., 1976; Devendra, 1982; Roxas *et al*., 1984; 1985) that straws from high yielding varieties produce better nutritive value than the traditional varieties. The higher concentration of ADL (lignin) and silica in MR 211 may be attributed to its agronomic characteristics as having short stem height. Variety with short stem has high lodging resistance which is closely related to high distribution of lignin and silica that strengthens the plant structure. The *in vitro* true organic matter digestibility (IVTOMD) was slightly decreased by 6%, due to increased nitrogen application from 0 to 240 kg N/ha. Although, the *in vitro* digestibility of true organic matter (IVTOMD) decreased a little, but the change was so small that it is of no practical importance. The results from

correlation between the yield performance, agronomic characteristics (grain yield, stem height and leaf: stem ratio) and straw nutritional properties (crude protein, NDF, ADF and IVTOMD) suggests that rice varieties with good agronomic characteristics produced straw with better nutritive value. The correlation result implies that high yielding rice varieties has potential to produce straw with improved crude protein and digestibility and low cell wall (NDF) and fiber (ADF) concentration.

CONCLUSION

The finding of this study not only indicates the importance of fertilization management practice on rice yield performance, but it highlights on the impact of these fertilization management practice on improvement of straw nutritive quality. The improved nutritive quality of straw due to current fertilizer practice is hoped to change the general attitude so that straws are regarded as a feed resource rather than a crop residue that needs to be disposed.

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